Interaction as exchanged actions and their role in visual and auditory feedbacks

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ENACTIVE

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This paper aims to point out an underestimated difference between "natural world" as "being given", and "machines" - as "being built"-, focusing on forces as intermediate wield variables to describe interacting complex dynamic systems whose co-evolutions cannot be described "phenomenologically". We will show that to obtain an observable closed-loop system, the relation between human and world have to be supported by a dual input-output paradigm, in which the input (sensors) and outputs (actuators) have to be linked with computational process that necessarily plays the role of a representation of the physical material object. We will then review several case studies that permit to question the shape, image, and sound relations.

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by Annie Luciani

1. A non conventional presentation of the Newtonian paradigm : In the world neither force nor feedback exists …

In 1687, an idea was born which changed people's approach towards the world and nature : Principia Mathematica was published by Isaac Newton and influenced humanity. The idea was that of interaction : action to / action from, formally expressed by the action-reaction principle. Previously, another representation system of the world, was proposed by Maupertuis, based on the minimum action principle, in which "action" has not the same meaning as that in the action-reaction principle. It had less influence than Newton's representation, until the rewriting of Newton's representation by Lagrange and Hamilton. As we know now, these two representational systems are totally equivalent for representing the dynamics of systems that are not at speeds close to the speed of light (relativity theory) and not at the atomic scale (quantum theory). Nevertheless they differ completely with regard to the concept of representation on which they are based.
As stated earlier, the first is based on, and only on, the idea of interaction. It expresses, step by step in time and space, the correlation of evolutions of observable phenomena. This means that it considers (1) at least two phenomena, and not only one, and (2) the phenomenological correlation – i.e. the phenomenological co-evolution of both, and not the evolution of one. The basic and non-trivial notions used are (1) the distinction between extensive variables (EV) and intensive variables (IV) and (2) the action-reaction principle (sometimes called mutual influences). These two axioms (the duality of the variables and the symmetry of the influences) are the two inseparable fundamentals of this concept of nature. We may say that it represents an algebra of interaction between two (not one) observed evolving phenomena. It means that the abstract – or representational - process starts (and after, may continue ad libitum with any number of correlated phenomena) from two evolving phenomena exhibiting an observable correlation. This concept is a differential concept, differential in time and differential in space.

The second is based on the analysis of the space of movements where a movement is a point on a 4D space (spatial variables and time). It considers all possible movements and it determines the rules that regulate the realized ones, via integrated variables such as energy, or motion quantity. These integrated variables are well summarized under the heading of the general term 'Maupertuis Action', leading to a minimum of an integrated quantity process. This vision is more a "geometry" of the motion space aiming at the topological and geometrical organization of this space, as it is elicited in the term" analytic mechanics". Although they are completely equivalent to explain and formulate the dynamic behavior of nature, in the Maupertuis' vision, the action – reaction principle is implicit and masked in an integral vision of time and space.

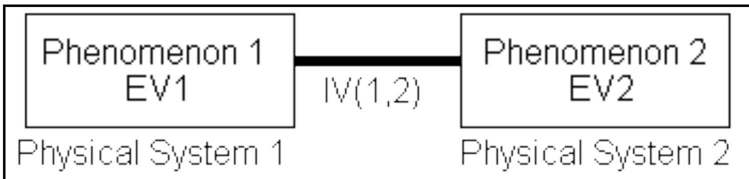
Due to the action-reaction principle, it is not possible in real world to talk about force feedback : intensive and extensive variables cannot be separated. Intensive variables are abstract descriptors: forces do not represent "things" but mutual influences. Extensive variables describe the states of the observed phenomena. Forces are only accessible through their effects on these states and these effects are not necessary the same on the phenomena that are under the same influence.

This point of view shows that action-reaction based formalism can be considered, rather than a representation of natural phenomena (Physics for Physis[1]), as an algebra of dynamics systems, implementing the interaction concept as “action to-action from”, i.e. “actions exchanged”, and not in the usual meaning of “action and feedbacks”, whatever be the type of feedbacks (for example, visual, auditory, etc…). Here, the feedbacks are also actions and are thus placed at the center of the representation of interacting systems.

2. Thus, when can we talk about force feedback?

First of all, one cannot talk of force feedback in the context of an interaction between physical objects (two physical objects, object/human body, etc…). It is impossible to say that the table on which the hand is, returns a force to the hand (please don’t be surprised and don’t stop reading!). It is no longer possible to say that the hand applies a force to the table. The interaction, i.e. the physical relation, is symmetrical and formulated by a non – oriented equating rule : [Influence 1->2 **=(equal)** -Influence 2->1].

Moreover, the physical rules that are able to represent the dynamic behavior of the table-hand system, are equating relations R = 0, that correlate intensive variables IV and extensive variables describing two observable phenomena (EV1, EV2) in the general form R[IV, (EV1, EV2)] = 0. The fact that there is no causality between these variables is elicited in this formulation. The force (Intensive variable) does not produce the displacement (Extensive variable) and vice-versa. This is the inseparable correlation [(EV1, EV2), IV] that describes the dynamics (i.e. the temporal co-evolution) of the two observed correlated phenomena [P1, P2] (Figure 1)



Two dual variables
Two dual non-oriented equations
EV1 (resp. EV2) = R [IV(1,2]
IV(1,2) = G[EV1, EV2]

Figure 1 - Non oriented and equating relation (interaction) between two physical systems

Consequently, talking about force feedback presupposes two major prerequisites:
(1) To split the non-oriented and coupled variables that are circulating in a physical “natural” system into variables that are oriented and separated,
(2) To link these two new variables by an input-output system.
Such representation or modeling process produces a non – trivial reformulation of the representation of the physical systems.

3. … Except in Human and electrical machines

However, there are two cases in which this decomposition is “naturally” implemented: the human machine and the electrical (or electromechanical) machines. In contrast to a physical object which is a “ single entity”, these machines are “broken” into four components: (1) sensors – (2) processing – (3) actuators embedded in a (4) mechanical morphology[2].

Thus, when one physical object “physically interacts” with a human being or with an electromechanical machine (including the computer), two completely different systems are in *vis-à-vis*, one that is not a sensor-processing-actuator system (figure 2 on the left) and one that is .(figure 2 on the righ)[3].

In what follows, we shall refer to the sensor-processing – actuator system as the SPA system and the Input - Processing – Output representations as IPO.

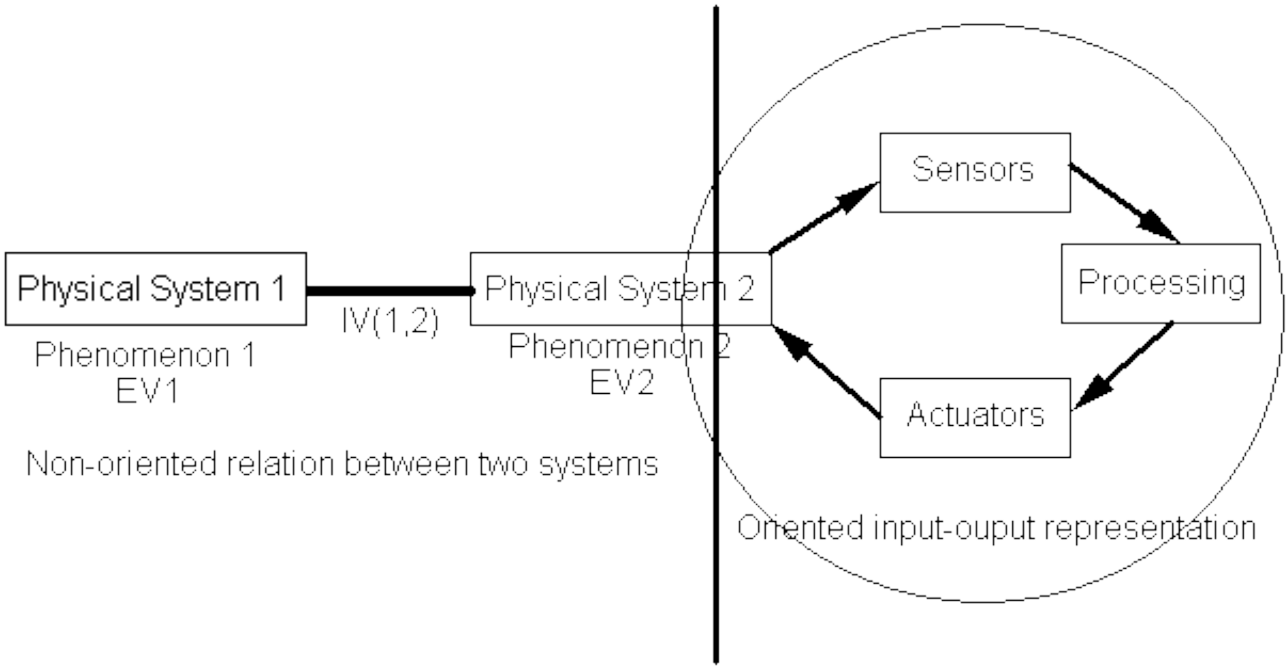


Figure 2 – System representation of the connection between a physical system and an input-output machine (human or electromechanical). On the left: The behavior of the physical system is necessarily described by pairs of non-oriented and non separable variables. On the right: Machines equipped with sensors and actuators (humans and electromechanical machines) that necessarily function with input-output oriented (arrows) and separable (separate paths) variables.

From this representation of the relation between the two types of systems, two others schemes can be derived:

(1) In Figure 3, the right side of figure 2 is depicted, representing only the human (or electromechanical) machines. It shows that these machines constitute a closed loop input-output system. The morphology (the physics of the body) represented by the circle is the component that implements the closure of the loop. This illustrates the role of the mechanical morphology in the study of human machines, as well as, of electromechanical machines (for example, haptic devices).

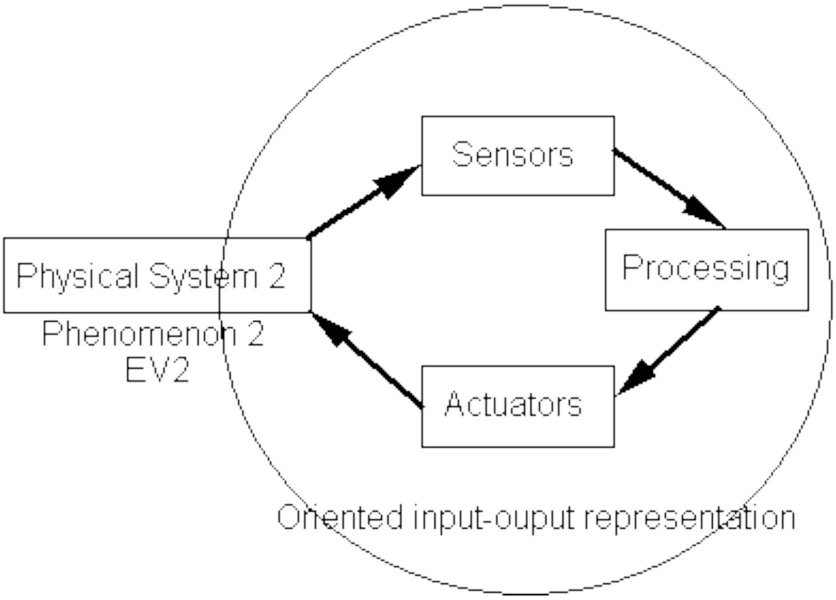


Figure 3 – The human machine as a closed-loop system

(2) Figure 4 illustrates the question of the relation between an input – output system and a non-input - output system. The mark of interrogation indicates the difficulty of coupling Physics and Humans (or non mechanical machines) and the difficulty of formalizing the closed-loop system between these two types of machines (mechanical object and sensor-actuators systems). This mark of interrogation is derived from the ambiguity and misunderstanding of the notion of force.

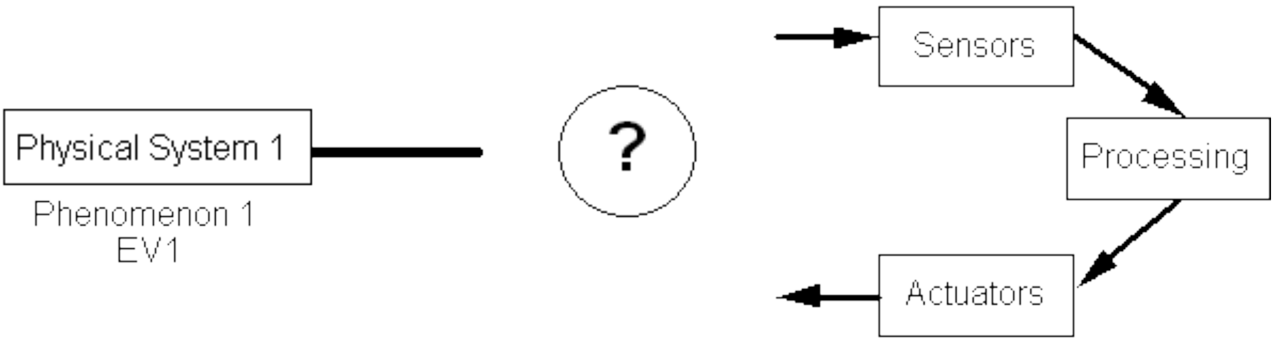


Figure 4 : Connecting the physical world and humans: the question persists

Let me be a little bit provocative:

Where are the forces in these diagrams (Figure 3 and figure 4)? Anywhere.
Let us suppose that the machine on the right side of figure 4 is an electromechanical machine. Let us assume that the physical system on the left is able to produce forces that could be sensed by the sensors placed on the right side of figure 4. The problem is that force sensors do not exist directly. There are always deformations or displacement sensors. A force sensor is composed of a calculation of the so-called "force", through an equation, which materializes mathematical hypothesis (such as linearity) from the sensing of a mechanical deformation of a specific material. For example, a force sensor made with strain gauges consists in the detection of the variation of the electrical intensity due to the variation of the resistance of a conductive material produced by the deformation of a mechanical material.

Thus, as is expressed by Newtonian formalism, forces are only an intermediate wield variables to describe complex dynamics systems, i.e. systems whose co-evolutions cannot be described “phenomenologically”, i.e.by Kinematics[4].

4. First Conclusions

1. As long as we aim to study directly the coupling between the human machine and the physical world, we cannot talk about force and force feedback. Moreover, the entire system implementing their coupling (Figure 4) is non-observable. Dynamics, and behind it, the notion of force and the principle of action-reaction of which the force is the formal descriptor, is a abstract representation of it. Dynamics is an abstraction, a “beautiful intellectual intuition, able to mentally re-generate for us the phenomenon” (As perhaps Kant would have said !).

2. To be observable, the side of this entire system that represent the natural world (the left of the figure) has to be equipped by sensors and actuators.

5. Thus, what about “force feedback devices” (FFD)?

The term “Force feedback devices” carries with it a number of presuppositions. As has been just stated, to render observable the problematic situation represented in figure 4, the left side has to be “artificially” equipped by sensors and actuators. Therefore, the physical system represented on the left of figure 4, is replaced by an input-processing-output observable system as represented in figure 5. A non-trivial transformation has been done, from a “single entity system” to an input-output representational system, and this is the only transformation that implements the conditions for defining force feedback and force feedback devices.

Notice that between the two circles, that represent the physical morphology of the systems in vis-à-vis, the mark of interrogation of the previous figure remains. I shall not discuss this question here.

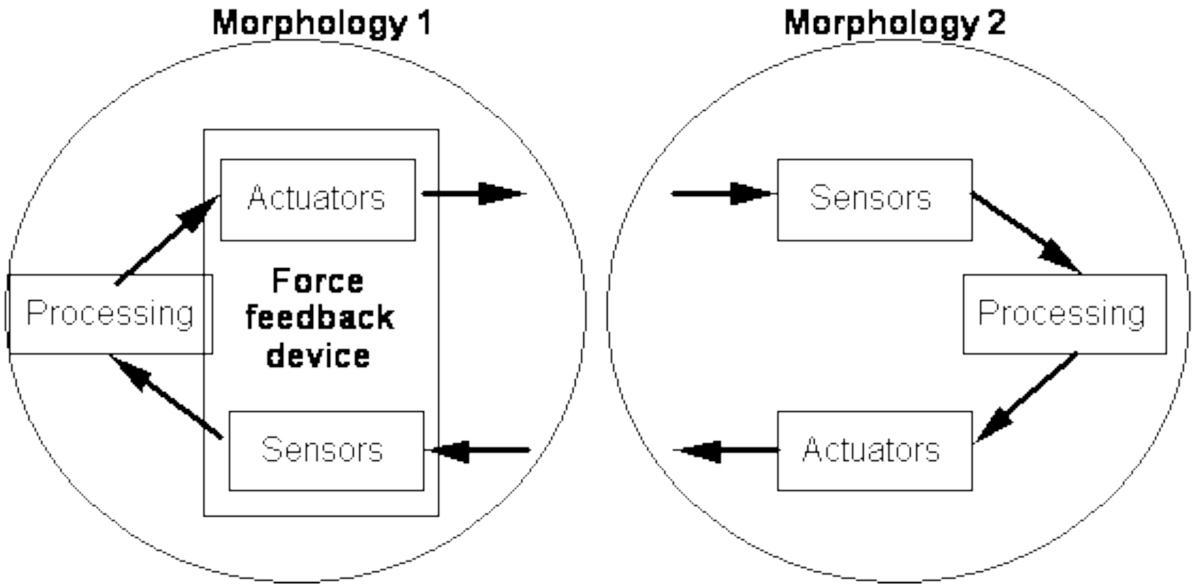


Figure 5 – The representation of the physical world as an input-processing-output system (on the left) and its relation with other input-output machines

We can underline the fact that FFD is a necessary artificial component, composed precisely of a pair of actuators-sensors, functionally linked by a computation process and physically linked by a mechanical morphology. For example, the actuator part of the device, as a motor, receives an electrical signal, this signal being the electrical representation (transduction) of what has been calculated behind the transducer. This means that what is commonly called a force-feedback device is only half of the equipment.

The entirely new system composed of the “connection” between the two input-processing-output systems, is composed of three closed – loop systems:

- Two of them are the closed-loop systems of the input-processing-output machines, on both sides (left and right) of the figure 5, closed through their morphologies.
- The third is the entire closed-loop system composed of the two previous loops.

This is the closed-loop system paradigm or interaction paradigm, as it is called in engineering sciences or in dynamic systems. We would like to point out here that these concepts cannot be supported only by the action – perception loop, on the side depicting human beings (on the right of the figures). It is necessary to introduce another process that closes the pairs of sensors-actuators (as shown in figure 5).

6. The central role of the processing that links inputs and outputs

We have shown in the previous paragraph that to obtain a closed-loop system able to represent in a dual input-output paradigm, the relation between human and physical object, the sensors and actuators on the left side of the figure have to be linked with a computational process. We would like to point out here that this computational process necessarily plays (even if we don’t want it!) the role of a representation of the physical material object (Figure 6).

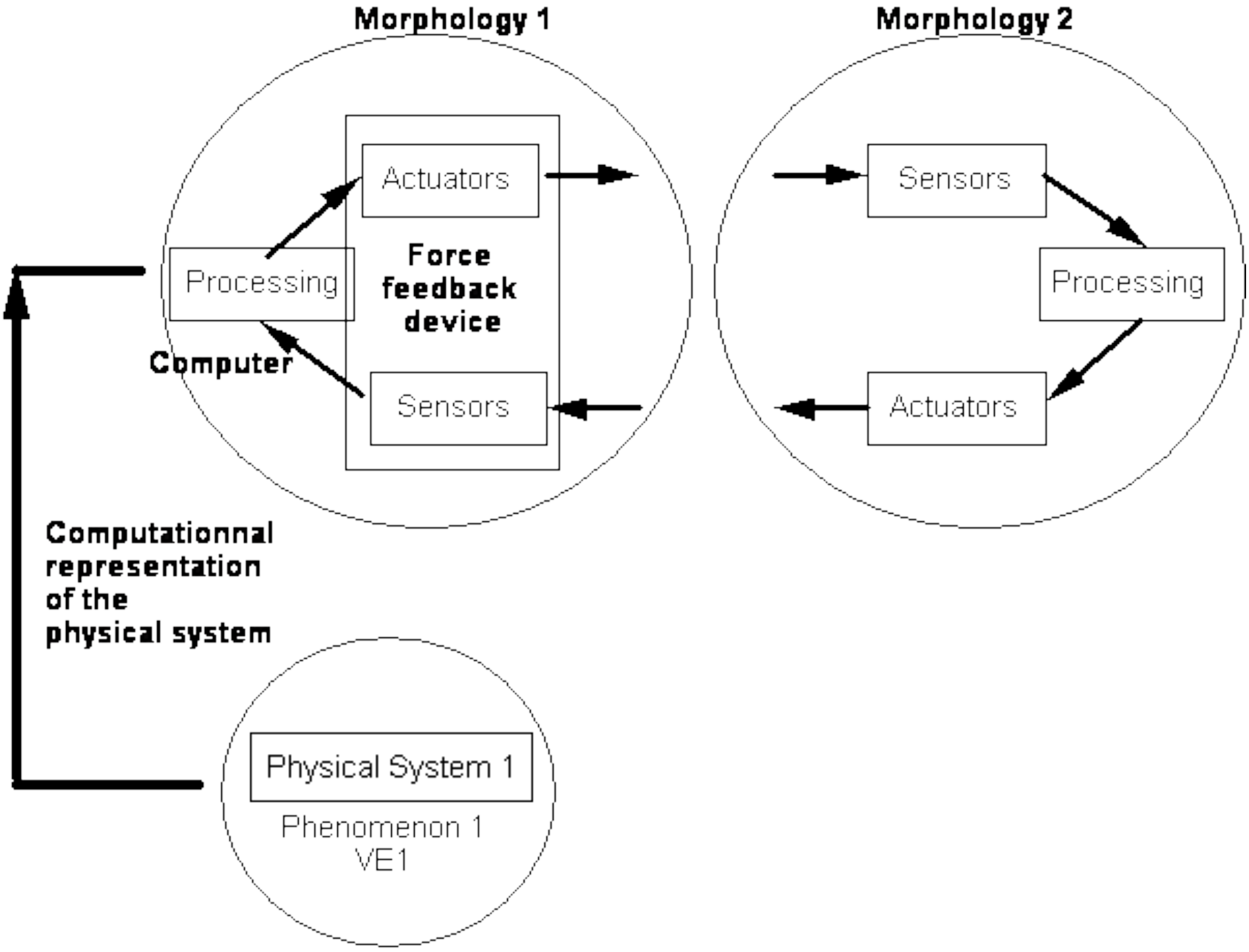


Figure 6 – The computational process as a representation of the physical material object.

Finally, thus we obtain a strange scheme in which the computer (understood as a generic electromechanical machine[5]) plays the role of a SPA representation of the physical world.

This machine, so equipped and as a component of the closed loop system composed with the human machines, looks like the Janus figure (Figure 7): on one side, it looks at (and it looks as) the physical world, and on the other side, it looks at (and it looks as) the human machine. It plays the role of an "interface", but not only in the sense of a material component placed between two systems of different nature, but more as a bi-faced representation.

It is probably the latest (and for the moment the best) instrument humans have invented to scientifically explore the complex, paradoxical, magical, relationship between human beings and the physical world.

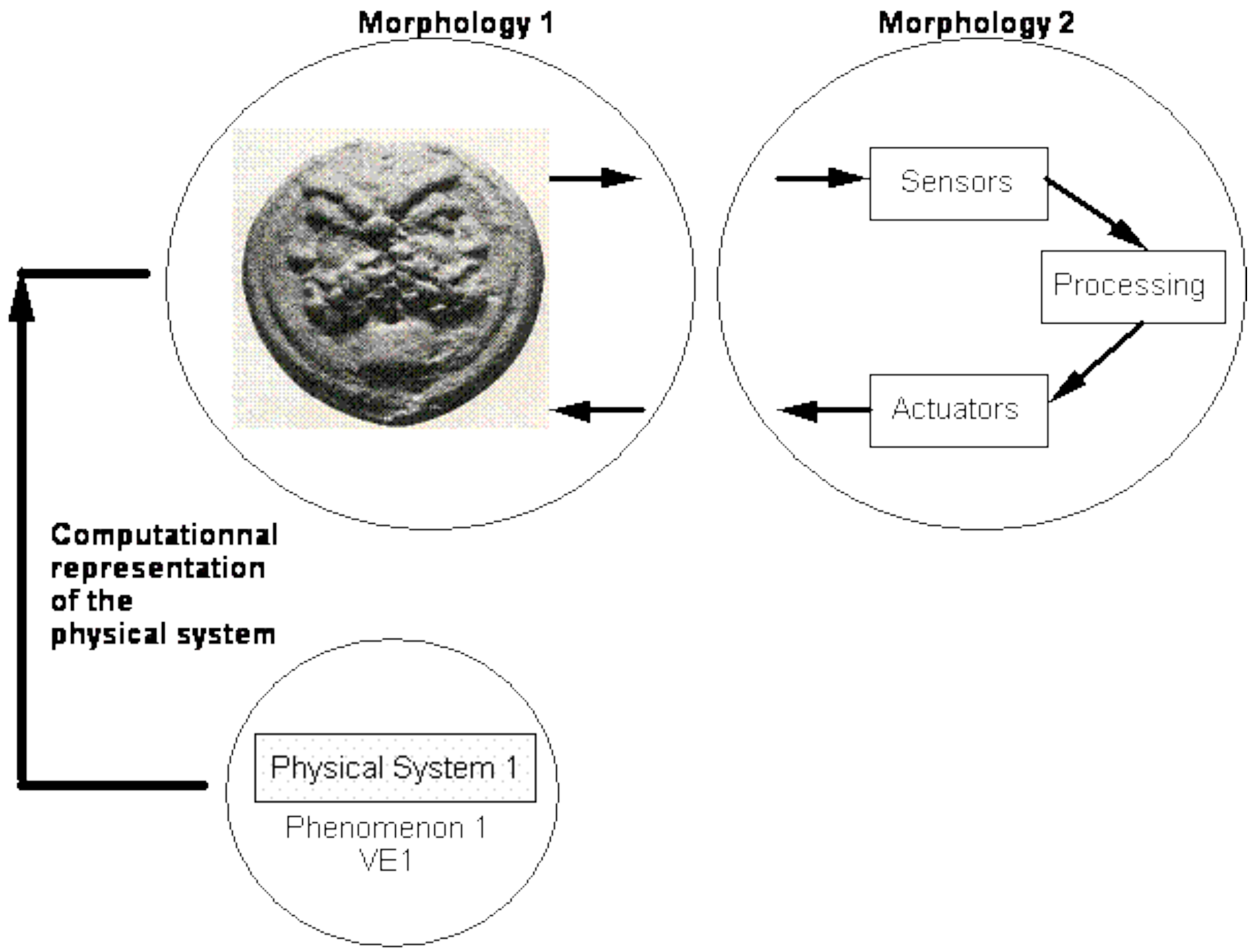


Figure 7 – The equipped Computer as the Janus Figure

7. Second conclusion

1. The corner stone of studies concerning the link between action and perception (on the human side) or symmetrically the genuine tangibility of the natural world (on the other side) seems to be not only the sensors and actuators by themselves, but also the process that links the two of them, called the “model” in VR or in automation. This model has to be simulated for producing “consistent” links between its inputs and outputs according to the outputs and the inputs of the second reflexive system.

2. At the core of these studies, there are disciplines[6] as computational physics, automation, regulation and control, (which were called Cybernetics in the beginning), that propose theoretical backgrounds, results and theories to formalize and express: (1) the transformation of non-oriented systems in coupled input-output representations and (2) the study of these connected systems as an entire observable system.

3. An interesting standpoint :
Could we picture Enactive, as the handshake between Newton and Gibson, via Kant (Noumenon as intellectual incompletely knowable beautiful intuition) and von Newman (computation and computational physics as materialized mathematics).

8. Some case studies

In the light of the theoretical considerations briefly sketched above, some typical and usual cases of the representation of human-objects relation can be analyzed.

1. Haptic display

Let us take the example of haptic display, which is the most simple case. Even in this case, we cannot avoid the question of what is the system that generates the force. For example, can a force feedback device be considered as a pure force generator as it is usually considered, and as it is often used in experiments in psychophysics? In Haptic display, stored data are encoded in electrical signals sent to the motor, that produces positions and resistance to displacements. The user cannot change these positions without producing an unusual effort[7]. In this case, the motor can be considered as a "force generator" mechanically felt by hands, in the sense that the supposed produced force is independent of the load put on it. This means that the user does not influence the behavior of the transducer and does not influence the process that controls this behavior. Thus, such a case is not an interactive situation. It is only a situation in which the positions are "sensed" by touching and the diagram of figure 4 can be represented by an open loop system. When the force (i.e. the electrical signal sent to the actuator) represents the intensive variable exchanged between the physical object represented in the computer and the hand, then we have an interactive situation in which the two objects influence each other. Thus, it is not possible to consider one or both of them as a force (resp. position) generator.
The data metaphorically haptically represented are equivalent to big masses that are not influenced by the manipulation. Consequently, the manipulation becomes thus an "exploration".

2. The trivial case of the object shape as a paradoxical case.

The visual shape and the mechanical shape of a single object have no reason to be always identical. Several situations illustrate this paradox. A rainbow or the mirage of an oasis in the hot desert, has a visual shape but doesn't have mechanical contour. We can traverse them or walk through them. Conversely, a perfectly transparent door has not a visual contour but has a hard mechanical shape. In usual rigid objects, the visual shape seen by the eyes is at the same spatial location as the mechanical shape "seen" by the body. Although these objects are usual, nevertheless, they represent specific cases where the matter is 100% (99,99%) mechanically rigid and simultaneously 100% (99,99%) electromagnetically rigid (opaque). But what about flames, rainbow, water, fluids, translucent pastes, glasses etc…?
Furthermore, what about objects like cat fur or hair, that are not 100% (99,99%) mechanically rigid, and thus exhibit several mechanical contours. In other words, and in a funny way, all what it is happening in terms of "contour" as a primary cue of space organization, depends on the percentage of the optical and of the mechanical rigidity[8].
What happens in term of forces,? If you put a force sensor (as described in paragraph 2) on the palm of the hand when stroking a cat, the force detected (which is represented by the electrical current provided by the transducer) will be very low when the hand is in the fur, higher when it is on the deformable skin and higher when it is touching the skeleton. This means that a single thing – your preferred pet - exhibits several mechanical contours, described by several thresholds in the singularities of the physical interaction sensed by the force sensor.

3. The case of the visual events and vision as non-problematic case in this context.

Basically, the visual features are not anything else other than the singularities of the interaction between photons and electromagnetic matter that can be represented by an open-loop system. The visual shape (the visually detected flatness, the visually spherical shape etc…) is the geometrical locus of the spatial singularities of the interaction light – optical matter. Thus, visual events are intangible. Other classical examples could be geometrical drawing and synthetic 3D images produced by pure geometrical representations.

4. And what about sounds?

Audition is, as vision, exteroceptive perception. Does it mean that sounds are, as visible features, immaterial? Is Music the sound of divine or celestial spheres? Obviously not. Sound does not exist without mechanical matter with inertia (not neutrino) and minimal rheological properties, as at least elasticity. The minimal system to produce sound is a second order differential equation system. Sound is the mechanical behavior of an inertial and rheological matter and its morphological and topological organization. It encodes (encapsulates) in a single signal all the properties of the material object. In addition, it conveys all the properties of this mechanical matter: material, structure, etc… on the larger spectra of temporal characteristics (from some Hz to several tens of KHz). From this point of view, it is the best "distant" and "diffuse" representation of what the material object is. It is the exteroceptive sense of touch.

5. And what about sounds, shapes and image relations

From the previous observations it can be said that, as for the visual and mechanical shapes, there are no a priori reasons in the natural world that proves that a genuine link between sounds and image exists, except through a specific contextual concordance between the two matters: mechanical and electromagnetic. This means that the relation is either arbitrary and metaphoric, or non-direct through matters and action. The question is then: If such links exist in humans, what are they? Several observations and current researches in the developmental process of newborns could be of great interest to provide the Enactive Interfaces project with valuable ideas and insights. For example, an important assumption (cf. ADAPT European project) seems to be that the cross-modal touch-vision recognition should be more effective when children (about 20 months old) "know" the name of the object. Correlated to the unexpected phenomenon of a temporary disappearance of the visual orientation towards auditory sources around 1 to 2 months of age and its reappearance around 3 to 4 months and having in mind that sounds represent better than vision and like touch, the inertial and rheological properties of the matter, this should suggest that naming should be a necessary component to optical matter and mechanical matter after 4 months of age (and later in the adult stage).

9. Final conclusion

All the considerations presented in this talk lead to the following conclusions:

(1) Matter, with its two different aspects (photon with no mass, and "graviton"), that can be considered as TWO MATTERS, is (are) at the core of the discussions of what we feel, of how we can act on, of how we build our representations of the world, etc…

(2) An observable representation of matter enables the representation of a physical system in three oriented computational components, constituting an SPA system.

(3) These oriented computational components convey input and output signals.

(4) The corner stone of the problem of interaction does not consist in these input-output signals by themselves (in humans as well as in the representation of objects), but in the correlation between them, this correlation playing more or less, the role of a representation of the matter.

(5) We assume that such “evoked” or “represented” matter plays a central role in Virtual Reality to trigger the sense of Presence of virtual objects, as well as in the constitution of our mental representation of the tangibility of objects.

(6) The entire artificial system can be progressively defined in vis-à-vis of human system, seen as a MIMESIS, can be thought of as a core component of Enactive interaction and Enactive Interfaces. It will be used to create a new mediated “Enactive” relation between humans and world.

Notes:

1. “Physis”, in ancient Greek, means Nature, as “Being given (to the humans)”. “Mathematé” means “being done (by the humans)”.

2. I am not discussing in this lecture what this decomposition allows. I would like only to point out an underestimated difference between “natural world” and “machines”, between “Physis” as “being given”, and “machines” as “being built” (including living machines).

3. A simple historical analysis of our instruments shows that an epistemological break occurs in our instruments once the electricity appears. The integrity of the mechanical object was broken through electrified instruments. They are organized in pairs of associated actuators – sensors : microphones and loudspeakers that create an “auditory person only”; cameras and displays that create a ‘sighted person only”, mechanical sensors – actuators that create a “mechanical person only”.

4. In ancient Greek Kinema = Motion and Dynamé = Force

5. The only, though not minor, difference between a non-computerized electromechanical machine and a computerized one is the fact that computers are discrete machines.

6. Not only Physics, because Physics aims at developing only knowledge models of the world called theories (of Nature).

7. The objective concept as force and subjective ones as effort or tiredness have to be distinguished There is no bijective relation between the psychological space and the objective data or the mathematical concepts. As an example of this difference, we can take the case of the difference between the frequency spectrum and the auditory patterns that are objective features and the pitch or the timbre, that are subjective ones.

8. For free time in holidays: what do we feel when we grasp with our hands a parallelepiped piece of ice (except the temperature)?